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ABSTRACT

Futurism is currently divided between two bitterly struggling camps. "Cornucopians" tell of the wonderful future that technology will bring and reassure us that our problems are not serious. "Jeremiads" warn of impending doom if something is not done about the particular problem troubling the futurist. Jeremiads include environmentalists, some (but not all) resource specialists, and those concerned about the rate of population growth. The debate between these two groups was sharpened in 1981 by the U.S. Government publication "The Global Report to the President: Entering the Twenty-First Century" and an article by Julian Simon ("Resources, Population, Environment: An Oversupply of False Bad News") published in "Science," volume 208, June 27, 1980, pages 1431-1437. The thesis of this paper is that there are logical flaws and oversights in the Cornucopians' approach that make the debate fundamentally asymmetrical. The Cornucopians have made assumptions and chose methodologies that simply ignore or dismiss the most critical issues; this has led the Jeremiads to their current concerns. Cornucopian fallacies and the reasoning processes and flaws/omissions characterizing the analyses of Simon and of Herman Kahn are discussed. (JN)

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THE ENVIRONMENTAL FUND

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"All things are good, everything is best."
—Dr. Pangloss' dying words in Voltaire's *Candide*

"I set watchmen over you, saying, Hearken to the sound of the trumpet.
But they said, we will not hearken." —*Jeremiah* 6:17

About the Author

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Introduction

Since most of us would admit that we cannot really foresee the future, futurism would seem a gentle game requiring a sense of humor and considerable tolerance.

Not so. The field tends to be divided into two bitterly struggling camps. Each camp is itself a loose federation, but in broad terms the battle is joined between:

—those who tell us of the wonderful future that technology will bring and who reassure us that our problems are not serious; *vs.*

—those who warn of impending doom *if something is not done* about the particular problem troubling the futurist.

The first camp (generally dubbed the "Cornucopians")[1] has been most flamboyantly characterized by some science fiction writers, but it was augmented a decade ago by the entry of Herman Kahn, Director of the Hudson Institute, into general-purpose futurology.[2]

The second camp—the "Jeremiads"?—is clustered about environmentalists, some (but not all) resource specialists, and those concerned about the rate of population growth.[3]

The debate has strong political overtones. If things are going well, we don't need to do anything about them. A useful argument for *laissez-faire.* If something is going wrong, the Jeremiads usually want the Government to do something about it. The debate thus gets mixed up in the current reaction against "petty government interference" and a generalized yearning to return to earlier, more permissive economic and political practices.

Moreover, one's position in this debate largely shapes one's attitude toward population growth and on the current issue of whether to impose more effective controls on present high levels of immigration.

The debate was sharpened in 1980-81 by two developments. In July, 1980, the U.S. Government published the *Global 2000 Report.*[4] In June, 1980, a new and particularly uncompromising Cornucopian appeared on the public scene with the publication in *Science* of an article entitled "Resources, Population, Environment: An Oversupply of False Bad News",[5] by Julian Simon, an economist at the University of Illinois.

The two events have been followed by a torrent of critiques, counter-critiques and new publications. Some of this exchange has consisted of challenges to the *Global 2000* projections; more of it has centered about Dr. Simon's use or misuse of statistics.[6] As a confessed Jeremiad, this writer finds it hard to believe that any dispassionate reader, comparing Dr. Simon's writing with topical treatments in the *Global 2000* study, would find them on the same plane, but we will leave it to the avid reader to pursue the detailed argumentation elsewhere.

There are other fish to fry. In this paper, we will explore a broader conceptual question. The thesis of this paper—frankly partisan—is that there are logical flaws and oversights in the Cornucopians' approach that make the debate fundamentally asymmetrical. The Cornucopians have made assumptions and chosen methodologies that simply ignore or dismiss the most critical issues which have led the Jeremiads to their current concerns.

If we can persuade others to address the issues that concern Jeremiads, the debate will be sharpened and improved, and it may be fruitful. There can be real and legtimate differences in identifying current trends and in deciding which ones are important.

The Conflicting Perspectives

First, it may be useful to present characterizations of the two opposing world views.[7] Here is a capsule description, from *The Global 2000 Report,* of its findings:

> "If present trends continue, the world in 2000 will be more crowded, more polluted, less stable ecologically, and more vulnerable to disruption than the world we live in now. Serious stresses involving population, resources, and environment are clearly visible ahead. Despite greater material output, the world's people will be poorer in many ways than they are today.
>
> "For hundreds of millions of the desperately poor, the outlook for food and other necessities of life will be no better. For many it will be worse. Barring revolutionary advances in technology, life for most people on earth will be more precarious in 2000 than it is now—*unless the nations of the world act decisively to alter current trends.*" (emphasis added.)

Dr. Simon: "The facts, as I read them, point in quite the opposite direction on every single important aspect of their prediction for which I could find any data at all."[8]

Dr. Simon: "The standard of living has risen along with the size of the world's population since the beginning of recorded time . . . And there is no convincing economic reason why these trends toward a better life, and toward lower prices for raw materials (including food and energy), should not continue indefinitely. Contrary to common rhetoric, there are no meaningful limits to the continuation of this process."[9]

Mr. Kahn: ". . . 200 years ago almost everywhere human beings were comparatively few, poor and at the mercy of the forces of nature, and 200 years from now, we expect, almost everywhere they will be numerous, rich and in control of the forces of nature. The 400-year period will thus have been as dramatic and important in the history of mankind as was the 10,000-year period that preceded it . . ."[10]

The first *Global 2000* statement is a warning of consequences of failure to address perceived problems. The two Cornucopians' statements are predictions. Dr. Simon quoted the *Global 2000* statement and, in order to rebut it, he changed it. By dropping the italicized phrase at the end of the quotation above, he transformed a conditional statement into a prediction, which he then attacked.

This is the first asymmetry. The proponent of corrective action does not need to predict; he is—or should be—simply warning of consequences if trends are ignored. The Cornucopian, on the other hand, must predict. If he takes the Simon view, he promises that you need not worry, because good

things will happen if you let nature take its course. Kahn is sure that the problems will be solved and that we may expect a glorious future. Either way, prediction requires a lot of faith.

A *projection* is a call to action; a *prediction* is an assertion that foresight and volition will not change the course predicted, and it is an invitation to inaction.

Moreover, no study can legitimately claim to be a prediction unless it addresses all the significant variables. As the *Global 2000* study repeatedly underlined, it was warning of trends, not predicting. It explicitly omitted many variables critical to a prediction, such as political and economic decisions, the prospects for international and domestic tranquility, and the implications of a series of bad crop years.

Don't reduce the debate to an exchange of predictions. We will all probably turn out wrong.

The real issue is whether the problems identified by the Jeremiads are valid ones.

On this issue, more later.

The Cornucopian Fallacies

These two Cornucopians' argumentation is seriously flawed as a tool for identifying the real and important present trends. It is flawed because:

—they pay little attention to causation and they project past economic trends mechanically;
—they casually dismiss the evidence that doesn't "fit";
—they understate the implications of geometric growth;
—they employ a static analysis which makes no provision for feedback from one sector to another; and
—they base their predictions on an extraordinary faith in uninterrupted and even accelerating technological progress.

To justify this harsh judgement, let us look into some of the Cornucopian fallacies, the reasoning processes and omissions which characterize Simon's and Kahn's analyses.

Extrapolating Past Growth: The Wrong Methodology

Simon argues that the past is the best guide to the future. Perhaps, but much depends on what part of the past you look at. He devotes most of his effort to demonstrating in various ways that mankind's economic lot has improved in the past century or so, which is not an issue.

Kahn extrapolates the growth trend with a line of reasoning which comes very close to economic vitalism. He projects "gross world product per capita" in 2176 at $20,000. As best one can gather from the text, this projection is based on a free-hand plot of "S-curves" (slow/fast/slow) of GNP growth for different categories of countries, drawn roughly from the U.S. and European experience.[11]

There are two problems here. First, analogy can be a dangerous process. To predict the future performance of the poor countries upon the past performance of the rich countries may involve too loose an analogy to justify the faith put in it. It assumes that the underlying factors are substantially identical. They are not. In contrast to Europe when it industrialized, poor countries today tend to have faster population growth rates, no colonies where capital can be mobilized, lower incomes (probably) and extreme foreign exchange problems, no technological lead over the rest of the world, and no empty new worlds to absorb their emigrants.

Second and even more important, gross national product (GNP)—or "gross world product"—is neither tangible nor real except in people's minds. It has no life of its own. It is simply a way of giving a numerical abbreviation to a sum

of economic activities. To project it as Kahn has done is to impute to it a separate reality. GNP is no more than the sum of its components, and the components themselves, the abstractions we call agriculture, industry, transportation, and services, are important to human welfare. The abstractions in turn are determined by the underlying realities on which they are built: the availability and quality of land, water, industrial raw materials; energy; technological change; the impact of population change on production and consumption; the productivity of the supporting ecosystems. And so on.

Proof of past success is no assurance of future well-being, and the mechanical projection of economic curves is hardly a reliable guide to the future.

The task of *Global 2000* was to take several of the most basic of those underlying forces and to analyze how changes in them may be affecting the potential for economic activity and human welfare.

In order to focus the argument more clearly, perhaps we should attempt to describe a general world view that lies at the root of population/resource/environment investigations such as the *Global 2000* study.

Most of us would agree that the general condition of mankind has been generally upward for a sustained period, at least until the past decade. Indeed, the scale of the growth is a new thing on Earth, and the very magnitude of the growth of population and of economic activity is the source of the issue. Let us phrase it thus:

> The hallmark of recent history has been explosive economic and population growth, supported by and supporting an extraordinary burst of technological change and mankind's first intensive exploitation of fossil fuels. The central question for the future is not "did it happen" but rather: "Can such growth be sustained, or does it itself generate dynamics that will bring the era to an end? If the latter, what will the changes be, and what if anything should mankind be doing to forestall them or shape them in beneficial directions?"

These questions are fundamental. They do not prejudge the question of whether humanity is at a major turning point; they simply say that we had better examine the evidence.

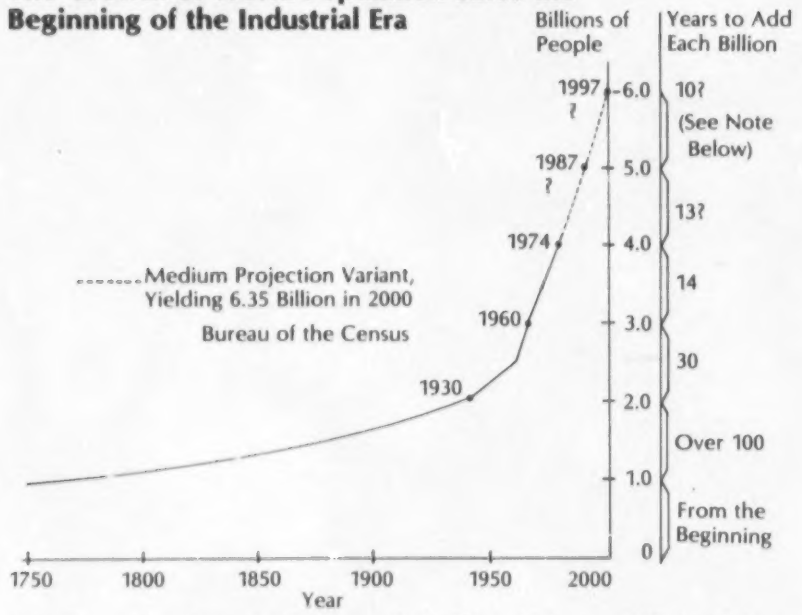
If the point about past growth needs to be dramatized, let us look at graphs of two key indicators.[12]

These curves are not in contention. The Cornucopians themselves use these or similar data to show that things have gotten better. What they suggest, however, is that—for the first time on Earth—population and economic activities have grown so sharply as to bring them into a new relationship with the scale of the Earth itself. This generalization applies to some of the basics: arable land; forest cover; fresh water resources; fisheries; and even the atmosphere and climate.

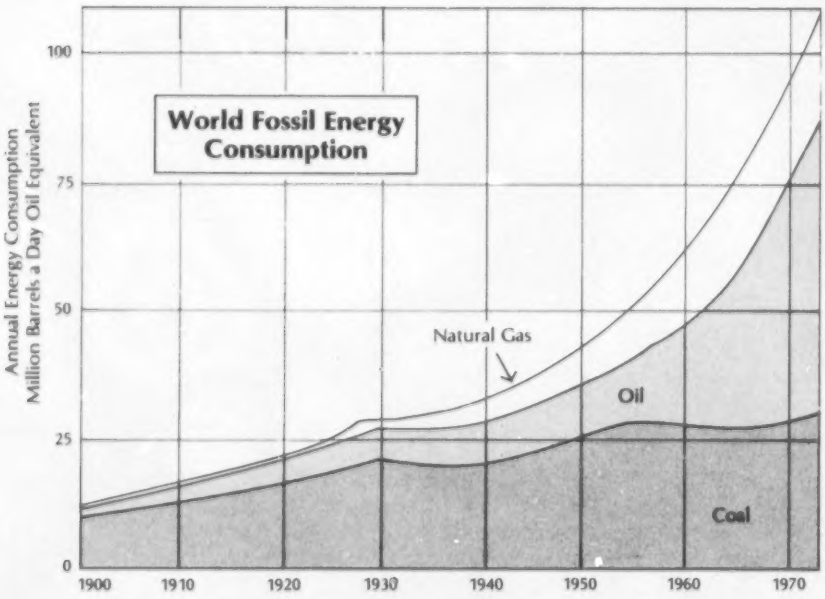
As a single example, let us take the question of carbon dioxide in the atmosphere. It is a useful example because it is directly related to the growth curves graphed and because it may turn out to be an extremely important issue.

In the past century—the period of industrialization and fossil fuels—the amount of carbon dioxide in the Earth's atmosphere has increased by about

The Growth of World Population Since the Beginning of the Industrial Era



Note: The number of years it will take to add the fifth and subsequent billions will depend primarily on the pace of fertility declines, and to a lesser extent mortality trends, in LDC's.



16%. The primary causes probably were the burning of fossil fuels and the reduction of the world's tree stocks as forests have been cleared for agriculture, converted to lumber or pulpwood, or consumed in cookstoves. Projections vary, but the amount of CO_2 may double in the next century.[13] The potential implications include a general warming of the Earth's climate and an alteration of rainfall patterns, and a rise in sea levels to cover low-lying coastal areas. As of now, amid widespread evidence of rising sea levels, it appears that U.S. Gulf and East Coast sea levels are rising about 300 mm per century.[14] Satellite imagery shows a decrease of 2.5 million square kilometers in the Antarctic ice pack from 1973 to 1980.[15] Recent data are still far from solid, but the global climate may have warmed 0.4° C in the past century, half of that increase having occurred since 1960.

It takes little imagination to recognize that rainfall and temperature changes, rising sea levels and perhaps the necessity to curtail fossil fuel use could influence future economic activities. To most of us, the fact that human activity is changing the very chemical composition of the air we live in would seem adequate justification to bring the issue into any consideration of current trends affecting the well-being of mankind. But nothing is yet established. We don't know how much of the observed change results from the causes cited. We don't know whether the existing scientific predictive models will prove valid, or how the man-induced CO_2 change will interact with natural climatic forces still dimly understood. We need more knowledge.

The Global 2000 Report devoted 14 pages to man-induced effects on the climate, focussing primarily on CO_2 but dealing also with issues such as particulates, albedo and man-made energy releases. It concluded that it is not currently possible to make agreed climate projections, but it also called attention to the problem with the note that:

> "none of the global long-term models used by the agencies for this study are capable of accepting climatalogical inputs. The energy, food, water and forestry projections all assume implicitly a continuation of the nearly ideal climate of the 1950's and 1960's . . . the scenarios are reported here to indicate the range of climatic change that should be analyzed in a study of this sort."[16]

Simon seems to have ignored the carbon dioxide issue.

Kahn discusses the problem along with other possible causes of a warming trend. He concedes that a warming trend might raise the level of the oceans, but he argues that "this would hardly mean the end of human society. Major shifts might be forced in agricultural areas and in coastal cities." He concludes that "it seems unlikely now that the carbon dioxide content will ever double unless mankind wants it to happen."[17] Thus cheerfully he dismisses this problem and thereby illustrates the curious inversion of his logic.

Why does he dismiss substance for "prediction"? He dismisses the real issues for fear they would lead his readers to lose faith in the future he has promised them. Would he not better join the Jeremiads and concentrate on telling his audience that if they want that future, they may need to take the carbon dioxide problem seriously?

Question: Which intellectual approach is the more valid way of attempting to understand current trends affecting human welfare?

If you seek a sense of what will shape the future, examine the issues generated by population and economic growth, do not simply extrapolate the growth.

Economic changes cannot be studied in a vacuum. One must assume that economic change is created by the interaction of the underlying physical realities and mankind's adjustments to them (e.g. technology, price shifts.) Unlike the Cornucopians, *Global 2000* probed the real question: Are the underlying physical factors changing?

The Lone Ranger vs. The System

No one person can be expert on everything. The separate technical literatures are simply too vast and too fast-moving. With this in mind, *Global 2000* called upon technical experts to describe the conditions and directions of movement in their areas of expertise.

The range of material to be covered was of course enormous. A list of the chapters in Part 1 of Volume II makes the point: Population; GNP; Climate; Technology; Food and Agriculture; Fisheries; Forestry; Water; Energy; Fuel Minerals; Nonfuel Minerals; and Environment (itself divided into sections dealing with each of the areas above).

These chapters usually report a range of views when the issue is controversial. The projections and conclusions were summarized and dramatized in Volume I. No effort will be here attempted to summarize the materials again; this paper is addressed to the Cornucopians' methodologies rather than to recycling the *Global 2000* conclusions.

Criticism of the *Global 2000* process is certainly in order. The effort was, by its authors' admission, not complete or definitive. The state of the art is far from ideal. Refinement of those assessments is a legitimate topic for inquiry and should be welcomed. There are plenty of mythical statistics floating around in this numbers-crunching society; those who spot the mythical ones do us all a service.

One can also feel a certain sympathy for the individual undertaking a critique of such a mass of material. For one thing, even a well-informed generalist is unlikely to match the specialist's command of his own field, and well-intentioned criticisms may simply miss a technical point.

However, to agree that it is difficult for one person to put it all together is hardly to condone unsuccessful efforts to do so. One cannot escape the feeling that some of the Simon/Kahn rebuttals of "bad news," whether in *Global 2000* or elsewhere, are directed more by polemical ends than by an effort to get at the truth. A few such casual hip-shots are more likely to generate doubts about the writer's credentials than to convince readers that bad news is false.

Since the reader has already been referred to a considerable body of specific rebuttals (footnote 6), a few examples should suffice to make the general point.

Simon on oil prices: ". . . the production cost of a barrel of oil has not risen, and probably has fallen, in deflated dollars . . . It is reasonable to expect that . . . the long-run downward trend in the price of oil will resume its course."[18] There is no effort to justify the statement, which is a remarkably casual

treatment of a complex subject that involves assumptions about the character of the market, the cost of finding new oil and of producing the marginal barrel, the likely trend of demand, the availability and appropriateness of substitutes, the expectations of producers and consumers, and indeed the theory of what determines prices.

Simon on land: Simon undertook to prove that a larger population does not mean more pressure on the land by shifting his argument from people/acre to farmers/acre. He then reaches the questionable conclusion that, although the trend toward fewer farmers/acre has yet to appear in the less developed countries, it will appear "as they get richer."[19]

Simon on fisheries: He expects the fish catch to go up. He offers no argumentation. He should have asked fisheries experts what is happening to the size and composition of the catch, to such technical measures of productivity as CPUE ("catch per unit of effort"), and to per capita trends.

Simon on the air: To prove that *world* air quality is improving, Simon cited some statistics on *U.S.* air quality in the early 1970s. His data were dated and limited, but they are nevertheless gratifying. He pays the environmentalists whom he excoriates the ultimate compliment of appropriating their work. If U.S. air quality has stabilized or improved in some ways in the past decade, it is at least in some measure the product of environmental efforts such as the Clean Air Act.

Kahn generally takes a subtler line. He too points to improvements in air quality, but he is quite willing to accept the need for some expenditures on air quality and other environmental measures and he includes "possible damage to earth because of complicated, complex and subtle ecological and environmental effects" among eight "real issues of the future."[20] In effect, his technique is to admit the possibility of environmental problems but to avoid focussing on them or attempting to measure their importance; he moves quickly on to extolling the brightness of the future and attacking those he deems pessimistic.

Kahn is, however, not above the quick and dubious rebuttal. To dismiss the possibility that nitrates from agricultural runoff may have an adverse effect on watercourses, his sole source is a paper presented in 1970 to a Midwest Fertilizer Conference.[21]

Simon, more than Kahn, makes points by shifting sources to show desirable trends (as in his treatment of population projections in his *Science* article[22]) and by using overall totals rather than trends per capita (as in his discussion of arable land).

The Cornucopians are slighting the resource and environmental issues which the Jeremiads consider the most important questions to be examined.

Static Models and the Lack of "Feedback"

There are indeed two ways of looking at the modern world. We have yet to absorb the immense implications of Einstein's $E=mc^2$. The Cornucopians stand tiptoe and breathless on the edge of wonderful new expectations. Simon writes:

> "Energy . . . is the 'master resource'; energy is the key constraint on the availability of all other resources. Even so, our energy supply is non-finite . . ."[23]

Certainly there are remarkable possibilities implicit in our growing awareness of what can be done with energy.

Hard on the heels of Einstein comes the silicon chip, followed closely by the new revolution in genetics. How can one not be exuberant?

The Sorcerer's Apprentice learned that immense power is not always benign to those who set it in motion. All of us—not just anti-nuclear activists—have learned many sobering things about nuclear power since 1945. Energy does not solve all problems. The sun has energy in abundance, but who would want to live there?

Enthusiasm may move mountains. Yet some important questions must be asked: How will you move the mountain? Where? What will be the results of moving it and putting it there? These are the questions the Jeremiads ask, and there are techniques such as input-output matrices and dynamic computerized models to help answer them.

In a way, both the Cornucopians and the *Global 2000* projective techniques are outdated. The difference (to use part of the Arab proverb) is that *Global 2000* knows that it knows not, while the Cornucopians know not that they know not.

Dynamic models enable the user to see the interactions of growth as it proceeds. Static models do not. As a very simple example: cohort models of populations permit the projection of changing birth, death and growth rates as the age composition changes; static models force the user simply to make assumptions about those rates and then crank out the results. At a more sophisticated level, dynamic models can incorporate assumptions as to how much energy, how much water, how much capital may be needed for economic growth at different stages, and can anticipate where shortfalls may appear because different sectors are competing for the same inputs. Such models can run projections of resource requirements or environmental by-products and permit us to see how much of a problem we face.

Global 2000 undertook to carry out as much as it could of this interactive process and found that the state of the system did not permit it to be carried very far. It concluded:

> "... the United States must improve its ability to identify emerging problems and assess alternative responses. In using and evaluating the Government's present capability for long-term global analysis, the Study found serious inconsistencies in the methods and assumptions employed by the various agencies in making their projections. The Study itself made a start toward resolving these inadequacies. It represents the Government's first attempt to produce an interrelated set of population, resource, and environmental projections, and it has brought forth the most consistent set of global projections yet achieved by U.S. agencies. Nevertheless, the projections still contain serious gaps and contradictions that must be corrected if the Government's analytic capability is to be improved."[24]

Kahn, on the other hand, simply projects economic growth and assumes that the necessary inputs will be available and that environmental problems will be surmounted. Simon does not address these questions in any integrated fashion.

For the best available survey of the interaction of population changes, economic activity, resource use and environmental implications, I would refer the reader to Chapter 13, "Environmental Projections," of *Global 2000*.

It starts with a description of the technique and a disclaimer:

> "The analyses are conducted in two steps... In the first step, the environmental implications of each of the previous driving-force and resource projections are analyzed. In the second step all of the environmental implications are synthesized and their collective impact back upon the driving-force and resource projections are considered. Were it possible to actually reflect these collective impacts in the earlier projections, the two feedback loops... would be closed. In practice, it is possible only to note the kinds of effects that could be expected, but without actually modifying the projections. Thus the feedback loops remain open at two points and the projections continue to be based on rather optimistic environmental assumptions."[25]

Having made the disclaimer, the study proceeds to examine literally hundreds of such interactions.

It is fascinating to follow the interconnected cause-and-effect process. The agricultural projections, for instance—themselves central to other major projections such as population and GNP—require certain assumptions about intensification of agriculture, a doubling or trebling of chemical fertilizer inputs (to a point where man-made introduction of nitrogen compounds into the biosphere will exceed the natural production), parallel increases in herbicides and pesticides, and reliance upon monocultures. These assumptions in turn generate questions concerning desertification, the conversion of forest and loss of forest cover, the effect of intensive agriculture on soil productivity, the impact of increased fertilizer application on watercourses and fisheries and perhaps on climate, the risks associated with pesticides and monocultures—all of which relate back to the initial assumptions about agricultural productivity and eventually to GNP and population assumptions. The degree of confidence concerning different interrelationships is made clear, and reference is made to the technologies that can help forestall or mitigate the harmful interactions foreseen. As *Global 2000* notes, in most cases the technology is available; the question whether to use it is a political and economic one.

There is nothing remotely approaching this sort of interactive analysis in the works of the Cornucopians. Until there is, the question remains whether they are even addressing themselves to the real issue.

> *Projective models are of little use unless they permit the study of the interaction of changing inputs, outputs and by-products of different sectors.*

The very speed with which technology is changing, the demands for economic growth posed by population growth, and the effort to raise living standards in the LDC's, all combine to force change at an unprecedented rate. The principal purpose of futurology should be to look as far ahead as possible, to study the implications of current and projected activity, to see how different sectors and issues interrelate. This is anything but a static predictive process. It should be a continuing process of probing and testing the potential consequences of different activities and directions of growth, of identifying the issues that need attention and the potential directions for beneficial change.

It was the lack of this capability, and the need for it, that *Global 2000* highlighted. A follow-up study made specific recommendations as to how

the capability might be improved within the U.S. Government. Simon and Kahn, standing aside and reassuring everybody that the future looks good, seem strangely irrelevant to this entire process.

If prediction is impossible, the real use of futurology is to suggest directions for the future and to foresee potential implications of present or contemplated activity. Global 2000 *urged the better use of dynamic models to make such analysis possible. The Cornucopians largely ignore the question.*

The Infinite Earth Fallacy: The Myth of Perpetual Growth

Simon chooses to avoid a simple mathematical reality: geometric growth can not be indefinitely sustained. He remarks that the "cumulative power of exponential growth models has the power to seduce and bewitch." Otherwise, he ignores it. This is akin to dismissing the proposition that 2 + 2 = 4. Geometric growth is as solid a mathematical proposition as simple arithmetic.

Let us cite three mathematical examples of the power of geometric growth, and preface them with the hope (probably vain) that the Cornucopians will not convert them into "predictions":

—"It is possible to calculate an absolute upper limit to the amount of crude oil the earth could contain. We simply assert that the volume of petroleum in the earth cannot be larger than the volume of the earth. The volume of the earth is 6.81×10^{21} barrels which would last for 4.1×10^{11} yr. if the 1970 rate of consumption of oil held constant with no growth. If the rate of consumption of petroleum continued on the growth curve of 7.04%/yr., this earth full of oil will last only 342 years."—Dr. Albert A. Bartlett.[26] Note that 7.04% was the annual growth rate of world petroleum use just before the oil shocks of 1973 brought about the beginning of conservation.

—Assume that we have one million years' supply of something—anything with a fixed supply—at current rates of consumption. Then let us increase the rate by just 2% per year (very roughly the current world population growth rate). Now, how long would the supply last? Answer: 501 years.

—At current growth rates, how long would it take for the world's human population to reach the absurdity of one person on each square meter of ice-free land? Answer: about 600 years.[27]

These things won't happen. Resources won't rise in a geometric curve until they are exhausted, and then plunge suddenly to zero. There will be changes in real prices, adjustments and substitutions—the whole pattern of constantly shifting realities that makes prediction impossible. The population will never remotely approach such a level. Long before then, birth rates will fall sharply, death rates will rise, or both.

However, the examples dramatize that the outer limits to current growth patterns are not so very far away. The modern technological revolution has created something genuinely new on Earth. There has probably never been sustained worldwide growth at recent rates, and certainly not to current levels. Consider Graph 1 again. Populations have

reached or exceeded the carrying capacity of their local or regional environments many times, and have sometimes paid the price of a population collapse, but human geometry for the first time requires that we think in terms of the relationship of population and economic activities to the entire Earth.

World population has risen from about one billion to about 4.5 billion in about six generations. The demand for resources and the environmental impacts have been more than proportional, because per capita consumption has risen. This is not a mathematical fantasy or a projection for the future. It is a description of current reality, whether the increase of atmospheric CO_2, the ingestion of chemicals into the human body, the number of people to be supported per acre of arable land, or the cubic meters of fuelwood to be cut.

The economic success that Simon hails and projects into the future is itself the source of present problems, and what the mathematical examples above suggest is that there are real limits, and not so very far away, which lead inescapably to the conclusion:

Indefinitely sustained growth is mathematically impossible on a finite Earth.

This perhaps explains the Cornucopians' periodic obsession with outer space as a solution to raw material needs or an outlet for population growth. It may be wild, given the energy requirements even to escape from the Earth's gravitational field and begin the trip, but it is the only theoretical way out of the dimly perceived recognition that growth cannot go on forever on Earth.

There are several responses to this point about finiteness, none of them satisfactory:

* Kahn says:

"A basic change will occur in the character of the two fundamental curves of world population and GWP over time. Both curves should pass through a point of inflection (the population curve may have already passed through this point), so that from then on the metaphor of (worldwide) exponential growth will be increasingly misleading."[28]

This enables him to steer around the problem. He is partly right. Geometric growth will not continue to the absurdities suggested by the mathematical examples above. There are two problems, however, posed by his easy dismissal of geometric growth. First, he simply assumes that the process of growth has not already brought us to an era when it threatens some of the basic support systems for continued growth. Second, he posits his happy picture of 2176 A.D. on the assumption that growth to the levels he forecasts will not have such deleterious effects. (His optimism about population growth will be discussed later.) If he wants us to believe this, he'll have to demonstrate why, and to do so he will need to employ some dynamic analysis of the impacts of such growth upon resources (particularly fossil fuels and the so-called renewable resources) and upon the environment.

* It is argued that technology will save us, either by colonizing outer space or by finding substitutes.[29] This argument will be dealt with later in this paper in a section on technology.

* The problem is fudged by shifting the calculations. Projections for the

potential longevity of supply of raw materials are based on *current* demand rather increasing demand. Kahn and Simon both use this technique.[30] Since they are also assuming rising populations and rising per capita consumption, this is not an argument. It is a moonbeam. Bartlett's oil calculation above should have disposed of it permanently.

A more sophisticated variant is to say that GNP will rise, but not resource consumption, because we will be more efficient and we will be consuming more intangibles such as culture. Very likely, within limits. However, nobody has yet drawn a model of sustained growth relying upon the consumption of operas to feed the multitudes.

* It is suggested that the problem is so far away as to be irrelevant to those living now. Simon, in a bit of sophistry which he has probably come to regret by now, says:

> "the length of a one-inch line is finite in the sense that it is bounded at both ends. But the line within the end points contains an infinite number of points; . . . Therefore the number of points in that one-inch segment is not finite."

He then extends the analogy to copper and oil. He argues that we cannot know the size of the resource "or its economic equivalent," and he concludes that "Hence, resources are not 'finite' in any meaningful sense."[31]

This kind of thing is really pretty shocking. An inch of string is finite, even if it can theoretically be cut into infinitesimal pieces. The Earth is finite, even though we may differ endlessly about how much of a given resource may be available.

* Simon and Kahn have created adversaries out of straw, in order to push the argument about finiteness into some convenient future. They have considered nonfuel minerals, and Simon in his *Science* article quoted an unnamed adversary who conveniently and baldly asserts, "we are running out of natural resources and raw materials." All of them, apparently. In fact, *Global 2000* says of nonfuel minerals that "the projections point to no mineral exhaustion problems . . ." (Vol. I, p. 27)

In the longer term, if one assumes an unending increase in demand (as *Global 2000* does not), the problem of finiteness would of course arise. Ridker & Cecelski examined 17 nonfuel minerals and estimated the current annual growth in their consumption at rates from 2.9% to 9.2%.[32] One could plot those growth rates against any assumption about potential resources and demonstrate that growth in demand must eventually slow down and stop, but for the major ones (e.g. aluminum, iron, silica and magnesium) the real-world issue is not these theoretical limits but rather how to develop the energy to extract them, and in environmentally benign ways.

The most proximate resource issues identified by *Global 2000* center on food production for a growing population, the energy transition and certain key environmental problems. One may reasonably assume that the accommodations to meet these problems will force limits to the growth of demand long before nonfuel minerals exhaustion becomes an issue.

Philosophically, a doctrine founded on indefinite growth is untenable. Practically, the issue is to identify the priorities, to recognize which growth poses dangers and which does not.

The Population Sub-Case: The Contest to Cover the Earth

Population growth is such a clear and present issue. It is arguably the central one, since the product of

population X per capita rates of consumption

defines the scale of economic activity and total consumption, food and agricultural requirements, energy needs and concomitant environmental problems. It influences any effort to reconcile the desire for improved living standards with the carrying capacity of the Earth.

Kahn and Simon come to a parting of the ways here, and the difference is important, since the way in which one treats population growth shapes the entire character of the debate. Kahn thinks the population problem will solve itself. Simon says there is no problem.

To deal with the bolder assertion first: Simon sees indefinite population growth as beneficial. The assertion is unqualified. It apparently applies always, everywhere. This elevates it from theory to credo. (Despite his bald assertion, there are curious ambivalences in his various treatments of population. He argues at one point that "moderate" population growth is best for economic growth, which contradicts his thesis in *Science*. Elsewhere, he goes to considerable effort to persuade the reader not to be concerned about geometric growth since population has always grown in spurts before—thus he says you can afford to agree with him and yet not worry about the implications, since they won't come about. More surprisingly, he cites sources showing that population growth in Sweden and Egypt was periodically reversed by pestilence, invasion and famine.[33] His list is far from complete; he could have added citations of populations collapses of the Mayans, or the Anasazi, or a Sri Lankan empire, or Sumeria. And so on. Is this the man who professes such warm feelings toward his fellow-humans? Must one expect to rely indefinitely on such brutal population controls to avoid the lessons of geometry? We will return to this point.)

In his books, Simon undertakes to buttress his argument with historical arguments and economic models. An exegesis of his methods is beyond the scope of this paper.[34] The point here is that one cannot argue about resource availability for "hundreds or thousands of years" of population growth without running into the crudest of barriers: lack of space.

Resources and people are different. There is indeed room for the expectation that resources can be extended and substitutions made; in so far as this can be done, it modifies the mathematical models of geometric growth given above. The same can hardly be said about people.

The mathematical finiteness of the Earth operates with particular force with respect to its human population.

The intense and hostile reaction of the population/resource/environment community to Simon's *Science* article was particularly the result of his almost casual advocacy of unlimited population growth, unaccompanied by the sort of analysis of the by-products and interrelationships which, to his critics, are the most important issues raised by population growth.

Simon's argument, and Kahn's to a somewhat lesser degree, raises an interesting question as to goals. Kahn expects world population to stabi-

lize at 15 billion, give or take a factor of two. Simon, as we have learned, sees no limit.

Should population policy be set simply by a contest to see how many people we can support on the Earth? Is it indeed a legitimate or desirable objective to try to fill the Earth as tightly as possible with people? Is crowding an objective? Mexico City had 4.8 million people a generation ago. It has about 14 million now. It may pass 30 million within the next twenty years. Will it be able to accommodate so many? What will happen if it can't? How many Mexico Cities will it be necessary to create if mankind proceeds to test the carrying capacity of the Earth?

What kind of Earth? The Earth with 30 or even 15 billion people would be a very different place from now, and its carrying capacity might well be declining even as the population grew.

One might set population objectives in different ways. Most narrowly, one could ask "What population level would permit maximum consumption per capita under given assumptions about technology?"

To pose the question a bit less selfishly: "Under what population assumptions may we expect to achieve a harmonious and sustainable relationship between mankind and the planet?" (or "this country?" "this plain?" "this valley?")

Or to state a goal in keeping with man's august ability to affect the environment: "What human population levels would permit such a sustainable relationship with the Earth without forcing the entire system to be engineered to human requirements?"

This third formula is less arrogant than the other two. It leaves room for mistakes, if we should turn out wrong as to what we need in terms of space, land and water—or if we learn that the ecosystem cannot take as much tinkering as we thought it could. And it leaves some room for nature to continue its own experiments without mankind's arrogant supervision.

The population debate should be couched in terms of the numbers that can thrive on a sustained basis with the Earth's ecosystems, not simply in terms of how many people the Earth can support.

Unlike Simon, Kahn *assumes* that population growth will slow down and eventually cease at around 15 billion. This makes his logical problem easier. He doesn't have to wrestle with the indefinite growth fallacy. The Jeremiads' argument with him then boils down to two questions:

—Is the process automatic or should something be done to help bring about the stabilization?

—Is 15 billion the best number, or should we aim for a different one?

Kahn enters an area that has troubled the population community, and he does so with a circular proof.

He argues that population growth is slowing down and will continue to do so "as most of the world's people gradually become more affluent."[35]

Population growth will slow down at some point even if most of the world's people do not become more affluent, if only through the operation of the Four Horsemen. Most of us hope that it will be stabilized by limiting fertility rather than through hunger and rising mortality, and it is this point that Kahn is addressing.

The question, however, is "which comes first? Will rapid population growth itself prevent the growth of affluence which Kahn looks to as a population control?"

In the developed and industrialized countries, fertility has generally come down to around replacement levels—populations will eventually stabilize *if* immigration does not cause continued growth. It has also come down in most of the countries now industrializing, though not nearly so far. There is no magic in "replacement fertility"; fertility can and has fluctuated below and above that line in industrial countries. For the moment, however, the signs are hopeful in some of the more prosperous developing countries. In the poorer countries, and particularly in the rural areas, evidence of declining fertility is much more tenuous and uncertain. The subject would itself justify an essay.[36] For the purposes of this paper, it is sufficient to note that in most of the developing world the growth rates would still double the population in 40 years or less.

In fact, *Global 2000* and Kahn are not so far apart as he protests. The report's principal population projection (the U.S. Census Bureau median projection) anticipates a very small decline from 1.8 to 1.7% in the world's annual population growth rate, but this is a function more of the mathematics of demography than of pessimism. Even this small decline depends upon a 30% drop in fertility in the less developed countries within this quarter-century. Such a worldwide change in so fundamental a characteristic of human behavior would be dramatic indeed. Kahn himself does not have a projection, but he can hardly fault *Global 2000* for pessimism. Let us hope they are both right.

Kahn vehemently attacks a single sentence in *Global 2000's* 32-page treatment of population projections. He leaps upon a remark that population would reach 30 billion by 2100 A.D. if fertility and mortality were to remain at the levels expected in 2000. He has a point. The *Global 2000* summary does talk of such a population by 2100 "at present and projected growth rates."[37] This was an unjustified extrapolation from the technical volume. The point, however, remains that such a figure would be reached *if growth rates do not continue to decline.*[38]

Kahn is indeed in the midst of a controversy, even if it is not with *Global 2000.* He assumes that prosperity will be a sufficient contraceptive. Few in the population community are confident that the world will have a chance to try this cure. There is, however, a long-standing debate about whether family planning alone will be sufficient to bring population growth down, or whether nations will have to undertake stronger measures to discourage fertility, as Singapore has done for years and China is in the midst of trying. *Global 2000* stayed out of this debate. Kahn is welcome to join the debate, but if he wishes to pursue his thesis that prosperity will stabilize population growth, he needs to show that the rural poor in the LDC's—the great well-spring of population growth—are indeed moving toward prosperity, and that prosperity may be sufficient to bring about population stabilization.

And if he wishes to justify a figure of 15 billion as a sustainable world population level, he will need to marshal the sort of integrated analysis of population/resource/environmental relationships that he has so far avoided.

Technology as a Faith

Here we abandon the world of proofs and enter the blue, blue world of the empyrean. Technology is knowledge. It is very difficult to predict knowledge if you don't have it yet, and technological trends are among the least predictable of the forces that will shape our future. The Cornucopians are justified in reminding us forcefully of technology. A lot of people from Malthus on have underestimated it, and some Jeremiads still ignore it.

Let us agree on one point: the world has been experiencing a burst of remarkable technological growth.

Beyond that—although Kahn and Simon seem to have missed this point—the *Global 2000* report does not predict changes in the rate of technological growth. "In general, the analyses assume that the adoption and refinement of existing technologies will continue at about the same rate as in the recent past . . . and many of the quantitative forecasts extrapolate from historical data taken from the past two or three decades, which were characterized by many such breakthroughs. These forecasts implicitly assume, therefore, that breakthroughs will occur in the future at recent historical rates."[39] *The problems foreseen in Global 2000 are not the result of pessimism concerning technological change.* This approach may be faulted as too sanguine, since it assumes a continuation of an era of very high technological growth, but it is perhaps the safest projection given the relatively short time frame of one generation, and it certainly cannot be called pessimistic.

From here, however, we move to an article of faith among the Cornucopians that the more pragmatic among us do not share: that the recent high rate of technological growth will continue and indeed accelerate indefinitely. In attempting to prove that minerals will continue to get cheaper, Simon draws upon decreases in real mineral prices since around 1800, which in turn were made possible by technological advance coupled with the availability of cheap energy.[40]

For Kahn, the solutions to energy, and resource and food production issues rest upon technology, either by explicit reference to potential technologies on the horizon or generalized references to "improved technology." By way of example: "While food prices in real terms are likely to go up in the immediate future, there is little reason to expect a long-term rise. The application of capital and technology should be able to overcome any tendency toward diminishing marginal returns."[41]

Nobody has invented a way to predict technological progress. If we follow Simon's advice to use the past as a guide, it argues against too much faith. Human history has been characterized by spurts of technological growth alternating with periods of slow growth, dormancy or retrogression.

> *Technology may continue its recent phenomenal growth. It may not. It is an act of faith to assume that it will.*

If technology is as important as the Cornucopians believe—and they may be close to right—perhaps they should become Jeremiads along with us. Is it reasonable for rational people to assume with Dickens' Mr.

Micawber that something will turn up? Or should they be attempting to identify the policies which help promote technological growth, pressing for their implementation, and warning of the consequences if policy-makers fail to heed them?

Technology helped to generate the spurt in population growth that now concerns the Jeremiads. New industrial and agricultural technologies have created many of our present environmental problems. Other technology will almost certainly help us to correct our mistakes. A sensible observer with a feeling for history would be justified in assuming that those solutions will in turn generate new problems to be addressed.

Technology is not a panacea.

Even in straight economic terms, the Cornucopians make no effort to test their faith. Having satisfied themselves that technology *will* continue its progress, that it is always benign, that it will find new sources and substitutes for the indefinite future, Simon and Kahn then impose upon it the most stringent requirement of all: this must be achieved without increasing real costs. As we have seen with Kahn's remark about food costs, no effort is made at rigorous justification for the expectation that technological change will keep real costs down.

Both of them in fact make implicit or direct admissions that the premise may be false. Simon, for example, in attempting to show that one need not fear a shortage of copper, argues that copper can be obtained from other planets or even "made from other metals." To give him the benefit of the doubt, let us assume that he does not believe in alchemy, but that he is talking of creating copper by nuclear radiation. It would be interesting to know how the price of copper obtained by such means would compare with the present price of mined copper. Two physicists, as an intellectual exercise, have in fact tried their hand at such an estimate. They conclude that even ignoring such details as the 100-year half-life for nickel to decay into copper, and the fact that large masses cannot be irradiated, the cost of copper thus obtained would be perhaps 2.25 billion times as much as the present cost of mined copper, give or take about one order of magnitude. (See Annex to this Report.)

Kahn puts a few price tags on his technological excursions, but there is no indication that they are related to his GNP projections. At one point, discussing hydroponic farming, he says "a world 200 years from now with a projected GNP per capita of $20,000 could undoubtedly afford grain at even $500 a ton, five times the current price and our highest estimate . . ."[42] Was that $20,000 in constant dollars? If not, it is meaningless. If so, what other real prices might be rising, and how does the projected GNP figure reflect such adjustments?

Kahn is quoted as disagreeing "that the earth's resources are limited. 'I defy you to name one product of which we are now running out for which there is no substitute'."[43]

This approach begs the question. There are theoretical substitutes. As is regularly pointed out, silver is a better conductor of electricity than copper or aluminum, but it is not widely used. The question is "at what price; and what do you substitute for the substitute when you have diverted it to new uses? and for the substitute's substitute, as demand

increases." The argument that there is always a substitute is one of those convenient devices to avoid thinking about something. If you posit rising demand, you cannot hide from those questions, and you cannot simply hope that technology will find a nice, cheap substitute.

Simon relies on faith: "I do not believe that *nature* is limitlessly bountiful. I believe instead that the possibilities in the world are sufficiently great so that with the present state of knowledge, and with the additional knowledge that the human imagination and human enterprise will develop in the future, we and our descendants can manipulate the elements in such a fashion that we can have all the mineral raw materials that we need and desire at prices ever smaller relative to other prices and to our total incomes. In short, our cornucopia is the human mind and heart . . ."[44]

It would be wiser to recognize that technology can be of great help, and that it can itself create great problems. The resource base can be expanded. It can also contract if we misuse it, and technology does not automatically provide cost-efficient replacements for depleted aquifers, rangeland gone to desert, or lost topsoil. It would be wiser to maintain such resources rather than to pin our faith on substitutes.

If one chooses not to stake human welfare on unsupported faith in technology, a certain caution seems in order. Mankind will not have suffered if population growth is less than the advance of technology makes possible, but it may suffer very seriously if hopes for technology prove too high and if populations outrun the ability of science to support them.

Prudence would suggest that population policies be directed by a cautious estimate of what science and technology can do to support increasing populations.

We have all lived in an era when fossil fuels made energy very cheap. We must assume that there will be a continuing shift away from such fossil fuels—unless we simply assume with Dr. Simon that petroleum supplies are infinite and that prices will go down, and with him ignore the potential environmental and climatic implications of unlimited expansion of fossil fuel burning. If a transition to renewable sources is in order, we must at least consider the costs of the transition, in capital, in land and water requirements and perhaps in other ways yet unrecognized. And we must consider whether the shift could better be accomplished with a smaller than with a larger population.

Why the Debate?

What motivates people like Simon and Kahn? Why has Simon, particularly, been getting so much attention? If the flaws in his methodology are as apparent as has been argued in this paper, are they not apparent to editors and conveners of symposia?

As to his motivation, Simon is candid. On more than one occasion he has described a deep and prolonged state of personal depression he suffered when he still thought that population growth must be brought under control. He believes that the origins of that condition were not connected with the population issue but that:

> "As I studied the economics of population and worked my way to the views I now hold—that population growth, along with the lengthening of human life, is a moral and material triumph—my outlook for myself, for my family, and for the future of humanity became increasingly optimistic. Eventually, I was able to pull myself out of my depression. This is only part of the story, but there is at least some connection between the two sets of mental events—my population studies and my increasing optimism."[45]

This is a human enough reaction. Anybody who likes people would be happy to convince himself that more of them would be a blessing. It is a dangerous adviser, however, who "proves" what he wants to believe. It is said that Darwin became physically ill because he understood the implications of his theory for traditional beliefs, but he pursued the theory nonetheless. Is it not wiser to seek deeper understanding and eventually to accommodate our beliefs to it, than to make our inquiries justify our predilections?

Simon wonders whether his opponents may be responsible for a current mood of pessimism in the U.S. Kahn's motivation is more overtly political. Let him speak for himself about *Global 2000*:

> "... the real importance of this document lies in its impact upon people who are professionally concerned with environmental issues. In addition to government officials, this includes many college professors and public school teachers who are eager to exploit any respectable material which tends to support their pessimistic attitudes toward the U.S. economic and political system. *Global 2000* is tailor-made for this kind of exploitation.
>
> "Our society pays a heavy cost in terms of low morale when its establishment endorses the notion that our socio-economic system is, in effect, corrupt and evil. If the idea that more economic growth will pollute the environment and rob the world's poor further infiltrates our school system, we should not be surprised that young people prefer the Sierra Club and Nader's Raiders to Exxon and General Motors. The

upper middle class youngsters who graduate from our most prestigious colleges generally lack the kind of direct experience with work and hardships of any kind which breeds realism. They tend to be sheltered and idealistic—easy prey to those who deplore industrialism and economic growth as vulgar and materialistic."[46]

This second quotation follows a savage attack on the *Global 2000* study director, on its non-Governmental advisers (whose role in drafting the study Dr. Kahn seems to overestimate), and on the organizations with which some of the advisers are connected. The attack is similar to one launched by Simon in *The Ultimate Resource*. We have here a self-portrait of extraordinary intemperance towards others' viewpoints.

Dr. Kahn, in particular, is following a dangerous line of argumentation indeed. He is accusing his opponents not just of a lack of patriotism, but of actual subversion if they act as messengers of bad news. This is obscurantism of the worst sort. It presupposes a citizenry who will simply give up if all news isn't good news. A higher—and a more optimistic—estimate of human character would lead us to hope that people will address problems if they can correctly identify them. People are tougher-minded than Kahn seems to believe.

In the case of both authors, the urge to combat seems to have been intensified by that error discussed in Part II above: They have mistaken *projections* for *predictions*, and they feel it important to assert that the world is not going "to hell in a handbasket." There are Jeremiads who have fallen into the error of prediction, and some of them have made some excessively pessimistic predictions. It is not the purpose of this paper to defend them. The Cornucopians' present ostensible target, however, is *Global 2000*. The conclusions of that work are sobering, but they are cautious, as befits a bureaucratic product. The study deserves a serious examination of the evidence assembled. In other words—

Examine the Global 2000 *evidence on its own merits, not in terms of its impact on your mental state or the political motivations you impute to its authors or their associates.*

It remains to examine why so much attention has been focused recently on Dr. Simon and his views.

Dr. Simon looked at the same question from his end of the seesaw and wondered why doleful predictions receive so much press attention. He concluded in his *Science* article that "bad news sells books . . ." Perhaps—without having evidence other than a hunch to go on—we could rephrase that idea as "extreme views sell . . ."

It may simply be that Dr. Simon was on hand with a quick pen and some documentary materials ready for reworking when *Global 2000* brought futurism into widespread public attention. It is noteworthy, however, that his position on population growth has been at the extreme end of the spectrum, and his indictment of other views has been perhaps the most sweeping of any in recent print.

He may owe his sudden prominence to a sense of fair play. Editors, television programmers, Congressional staffers organizing debates are likely to look for somebody "on the other side," and Simon made it very clear that he is on the other side. More moderate people may not be so clearly identified.

There is a certain snowball effect. Editors and program arrangers pick up names from each other. Simon himself has attributed the recent attention to the publication of his article in *Science*, and he may be right. Publication in that prestigious journal seemed to legitimize his views and thus make him an appropriate participant in other events. His opponents picked up the flaws in his article, and the battle was on.

The point is important because it has given a particularly polarized cast to the present renewal of an ongoing debate.

Two other factors are almost certainly present. First, as was suggested at the beginning of this paper, there are strong political overtones. Those who wish to arrest or roll back the recent extension of government into population/resource/environmental issues need apologists, and Kahn and Simon are available and willing. Moreover, both writers put much faith in Adam Smith's "invisible hand," the price mechanism, as a benign means of adjusting to changing resource realities. The rationale can be used to justify diminution of the Governmental role. This emphasis upon the market mechanism assures Kahn and Simon of a favorable hearing among conservative economists. Few environmentalists are economists; almost none of them have considered ways in which the market can in fact help to address the issues that concern them, and there is a profound gulf between the worlds of the ecologist and the economist. Kahn and Simon are there to tell the economists that the ecologists are wrong, and it is reassuring. (Parenthetically, their positions have highlighted the need for serious study of the potential and the limitations of the market in addressing environmental issues.)

Finally, people like to listen to what they want to hear. Kahn and Simon reassure them that problems will fade away.

And Why Not a Debate?

To ask "why the debate?" is not to argue against having one. The population/resource/environment issue is quintessentially important. The more debate, the better, but let us look at the terms in which it is being carried out.

We are all—Conucopians and Jeremiads alike—trying to understand and describe a world in vast change. The technological growth on which the Cornucopians pin their hopes is itself part of that change, as are the population growth and the environmental by-products of technological growth which concern the Jeremiads.

We are all—except perhaps for a few nuts who enjoy human misery—interested in seeing the modern improvement in human welfare continue.

Nobody has all the answers. There should be a debate, but it would be more productive if it were less polarized and polemical.

It should not be posed as a choice between being for the system or against it. No system will last very long that doesn't dare to address the question: where is it going?

It should not be couched in terms of efforts to predict the unpredictable.

It should not be simply an effort to score debater's points; they will not be of much help in shaping the future.

Even if the techniques and the field are too new for *Global 2000* to have proved very much, the study certainly provided one answer to a fundamental question. There are indeed dynamics in motion, resulting from recent growth, that will influence the shape of the future. If this one point has been established and the Cornucopians agree to the need for continued examination of these forces, one may hope for a more beneficial dialogue.

There is plenty of room for legitimate challenge to the conclusions in *Global 2000*. Are the facts right? Are there better data? Are the important issues correctly identified? What are the best ways of addressing them?

Cornucopians by their nature tend to emphasize *solutions* where Jeremiads emphasize *problems*. An interchange can be useful. Do the Jeremiads overstate difficulties and fail to recognize new directions that can be helpful? Have we explored the opportunities presented by the oceans, by recent breakthroughs in biology, by electronics and data processing as thoroughly as we have explored the dangers from desertification, deforestation, and acid rain? Have we pressed for the elimination of legal and administrative impediments to beneficial change as eagerly as we have pressed for restrictive legislation?

If we urge the Cornucopians to recognize the problems, we should share their interest in promoting technological change which will help to address them.

The harm lies in the diversion of the debate into polemics. A continuing exchange of viewpoints, even between adversaries, is a useful way to pursue knowledge, and it may even identify some shared perceptions among all those who look to the future.

Those of both persuasions should remember that this is no single battle at Armageddon. Solutions will create their own problems, and problems their solutions. We should perhaps all recognize that only change is constant. And change is very fast right now.

We would ask of the Cornucopians that they accept as much. Growth such as we have witnessed cannot be indefinitely extended. We must all seek a sustainable relationship between people and the Earth. Most particularly, we must work out the implications of population growth. The issue cannot be: Should it stop? The questions are only: When should it stop? And how?

30

ANNEX

January 1, 1982

Drs. A. A. Bartlett and J. J. Kraushaar, physicists at the University of Colorado have provided the following calculations:

COPPER FROM OTHER METALS? WHAT IS THE COST?

Most feasible reaction, nickel^{62} → nickel^{63} → copper^{63}.

Note:

a. Nickel is more expensive than copper.
b. Only 3.37% of the nickel in nature is nickel^{62}.
c. The first reaction takes place in a reactor.
d. The second reaction is a spontaneous decay, with half-life for nickel^{63} of 100 years.
e. This means that to have 1 pound of copper^{63} at the end of the year, you would have to start with 144 lbs. of nickel^{63} at the beginning.

For simplicity, the rest of the calculations will assume that the production of copper^{63} is instantaneous—that there is no 100 year wait for it to be half-completed—on which unrealistically optimistic assumptions we calculate what the cost of producing copper in this way would be, calculating both dollar and energy costs.

The reactor produces 7×10^{12} atoms of nickel^{63} per second. That means 2.5×10^{16} atoms per hour. That works out at 2.5×10^{-6} grams per hour. Reactor time costs $10 per hour. So the cost of the nickel^{63} is $4,000,000 per gram. That means it costs $1.8 billion per pound. The present price of copper is ca. 80¢ per pound. Copper produced by this new way would cost 2.25 billion times as much.

ENERGY COST

Assume that ½ of the hourly charge is for energy. Assume a cost of 5¢ per kwh. It will take 200 kwh to produce 2.5×10^{-6} grams. Which means roughly 10^8 kwh per gram. (Really 8×10^7) A kilogram of copper will require 3.6×10^{17} joules of energy. Wyoming coal yields 33.2×1^{-7} joules per kg. of coal. Thermodynamic inefficiencies result in loss of ⅔ of the energy in producing electricity. It will take 33×10^7 metric tons of coal to produce 1 kg. of copper. There are about 100 tons of coal per railroad car. So it will take 300,000 RR cars of coal to produce 1 kg of copper; or about 150,000 RR cars to produce 1 pound of copper.

All this ignores that fact that the initial reaction can be brought about with only tiny quantitites of matter. No way to irradiate large masses.

The above calculations are approximate. They are thought to be accurate to within one order of magnitude (+ or −). That is, at the most optimistic, copper produced in this way would cost some $200 million per pound.

FOOTNOTES

[1] "Cornucopian" seems to be establishing itself as a non-pejorative and recognized sobriquet for writers of this persuasion. I am indebted to Marion Parks, who traces the usage at least to Samuel H. Ordway, Jr., *Resources and the American Dream, Including a Theory of the Limit of Growth* (New York: The Ronald Press, 1953). This use of the term should not be confused with the Cornucopia Project, established recently by Robert Rodale and others, not to predict but to bring about a more balanced and productive agriculture.

[2] Kahn's major work on futurology was *The Next 200 Years*, with William Brown and Leon Martel (New York: William Morrow, 1976). See also *World Economic Development: 1979 and Beyond* (Boulder, CO, Westview Press, 1979.)

[3] I offer this new use of the term as a somewhat self-deprecatory substitute for "Cassandras." She predicted; the "Jeremiad" warns.

[4] *The Global 2000 Report to the President: Entering the Twenty first Century*, Gerald O. Barney, Study Director, Three Volumes (Washington: GPO, 1980). Report prepared by the Council on Environmental Quality and the Department of State with the cooperation of a number of other U.S. Government agencies.

[5] *Science* magazine, Vol. 208, June 27, 1980, pp. 1431–1437.

[6] There follows a partial list of the polemical exchanges occasioned by the publication of the *Global 2000 Report*, on the one hand, and Dr. Simon's *Science* article, on the other. No attempt is made to list all the book reviews and letters to editors prompted by one or the other.

For the Cornucopians: Herman Kahn and Ernest Schneider, "Globaloney 2000" (*Policy Review*, Spring 1981 issue; The Heritage Foundation, Washington, D.C., pp. 129–147); Julian L. Simon, "Global Confusion 1980: A Hard Look at the Global 2000 Report" (*The Public Interest*, New York, No. 62, Winter 1981, pp. 3–20); Julian L. Simon, "World Population Growth" (*The Atlantic Monthly*, August 1981, pp. 70–76; other articles in *Atlantic* issues of June and July 1981); Julian L. Simon, *The Ultimate Resource* (Princeton: Princeton Univ. Press, 1981).

Against: Various "Letters" in *Science* (Vol. 210, December 19, 1980; pp. 1296–1308; with response by Simon); Stephen S. Rosenfeld, "The Anti-Malthusians" (*Washington Post*, Oct. 23, 1981); Barbara M. Baum, "Julian L. Simon's article 'Global Confusion 1980 . . . '" (analysis prepared for OES, U.S. Department of State, March 18, 1981, unpublished); Katherine Gillman, "Julian Simon's Cracked Crystal Ball" (*Public Interest*, Autumn 1981, pp. 71–89; with response by Simon); Paul R. Ehrlich, "Environmental Disruption: Implications for the Social Sciences" with supportive commentary by Earl Cook, rebuttal by Simon and counter-rebuttal by Ehrlich (*Social Science Quarterly*, Univ. of Texas Press, Vol. 162, March 1981, pp. 7–49); Garrett Hardin, "Dr. Pangloss Meets Cassandra" (Review of *The Ultimate Resource*, The New Republic, Oct. 28, 1981, pp. 31–34); Herman E. Daly, review of *The Ultimate Resource* (*Bulletin of the Atomic Scientists*, January 1982, pp. 30–42).

[7] This paper is confined to *The Global 2000 Report* and to the two most highly visible critics of it, Messrs. Kahn and Simon. Although none of these sources can claim to represent the viewpoints of other like-minded

people, the limitation is imposed to keep the length manageable and to avoid the danger of picking and choosing among opponents to score points.

[8] Simon, "Global Confusion 1980," p. 4.

[9] Simon, *The Ultimate Resource*, p. 345.

[10] Kahn *et al.*, *The Next 200 Years*, p. 1.

[11] Kahn *et al.*, *The Next 200 Years*; see especially Figure 5 on p. 56 and the accompanying text.

[12] Figure 1 from *World Population: The Silent Explosion* (U.S. Department of State Publication 8956, Oct. 1978, p. 3) modified by more recent Bureau of the Census projections from *Global 2000*. Figure 2 adapted from *Energy: Global Prospects 1985–2000*, Report of the Workshop on Alternative Energy Strategies, Carroll L. Wilson, Project Director (New York: McGraw-Hill, 1977) Figure 1-5, p. 17.

[13] See for example J. Hansen *et al.*, "Climate Impact of Increasing Atmospheric Carbon Dioxide," *Science*, Vol. 214, August 28, 1981, pp. 957-966, for discussion of CO_2 temperature relationships.

[14] Richard A. Kerr, "Whither the Shoreline?," *Science*, Vol. 214, Oct. 23, 1981, p. 428.

[15] G. Kukla and J. Gavin, "Summer Ice and Carbon Dioxide," *Science*, Vol. 214, Oct. 30, 1981, pp. 497–503.

[16] *Global 2000 Report*, Vol. II, p. 64.

[17] *The Next 200 Years*, pp. 175–176.

[18] Julian Simon, *Science* article cited, p. 1435.

[19] *The Ultimate Resource*, pp. 223–226.

[20] *The Next 200 Years*, p. 227.

[21] *Ibid.*, p. 119.

[22] "Between 1969 and 1978, UN and other standard estimates of the world's population in the year 2000 fell from around 7.5 billion to around 5.5 billion." (Simon, *Science* article cited, p. 1436.) This is not true of the UN projections, and the source (or sources) is a mystery. It may be that Dr. Simon has married two different sources, using different methodologies, to demonstrate a "trend." Sam Baum of the U.S. Bureau of the Census provided the following recapitulation of UN projections at the AAAS annual meeting in Washington, D.C. in January 1982.

Table 7. World Population in the Year 2000 as Projected by the United Nations at Various Times *(Population in millions)*

As assessed in year	Population in year 2000 (medium series)
1957	6,280
1963	6,130
1968	6,494
1973	6,254
1978	6,199
1980	6,119

[23] *The Ultimate Resource*, p. 49.
[24] *The Global 2000 Report*, Vol. I, p. 4.
[25] *The Global 2000 Report*, Vol. II, p. 227.
[26] Prof. Albert A. Bartlett, "Forgotten Fundamentals of the Energy Crisis," *American Journal of Physics*, Vol. 46, Sept. 1978. Available as a reprint from The Environmental Fund.
[27] The ice-free land area of the Earth is about 135.8×10 km. (*U.S. Statistical Abstract*, 1980; Table 1573, p. 897). The U.S. Bureau of the Census' 1981 estimate for global population in 1980 is 4.498 billion. Current rate of growth: 1.78% per year.
[28] *The Next 200 Years*, p. 188.
[29] Simon, *Science* article cited, p. 1435.
[30] See for example *The Next 200 Years*, p. 93, or *The Ultimate Resource*, pp. 32–33.
[31] *The Ultimate Resource*, p. 47.
[32] Ronald G. Ridker & Elizabeth W. Cecelski, *Resources, Environment and Population: The Nature of Future Limits* (Washington: Population Reference Bureau, August 1979), p. 22.
[33] *The Ultimate Resource*, Chapter 11, Figure 11-5 and 11-8.
[34] Simon's book *The Economics of Population Growth* (Princeton, 1977) contains most of the economic analysis on which Simon has based his later, more popularized and contentious works. It picks up the work of economists such as Kuznets, who obviously influenced Simon's thinking. Some of its principal conclusions seem unexceptionable:

> "Some may question the framework of this chapter on the grounds that the past rate of increase in knowledge, economics of scale, and productivity may not continue in the future. Perhaps. But even if so, this formulation should add to our understanding of the growth of population and per-worker income in the past history of the United States and Western Europe. And for at least a short period in the future, it does not seem unreasonable to project the long-term trend of the past. Further into the future we must bring other arguments to bear to help us decide whether the growth of productivity will be faster or slower than in the past. The same criticism may also be made about natural resources in the future, with the same response." (p. 133)

What he is saying here—despite his oft-repeated assertion that he is addressing the long term—is that the methodology is valid only for the short term.

A further note of caution is in order: Sharon Meluso of The Alan Guttmacher Institute, Washington, D.C. has analyzed Simon's citations of Kuznets and others and has raised serious questions as to whether Simon has correctly reported those authorities' conclusions concerning the relationship of population growth to economic growth and to well-being. (Institute memorandum dated January 12, 1982, unpublished.)

The point has already been made that much of Simon's argumentation seems to be directed to proving what is not in contention: that there has been improvement in per capita output. Two other brief points are worth raising. First, this sort of "proof" leaves unsettled questions of causation: is population growth the cause of increased productivity, or are they both products of a common cause? Second, elaborate statistical proofs require elaborate statistical inputs. Arguments about historical

trends in 19th century Europe may be flawed, since much of the data was constructed long after the fact. GNP analysis, after all, did not even come into use until the 1940s. For the poor countries, the statistical problem is even more serious, because of the very suspect quality of the data. As one who—unwillingly—helped to "create" the GNP data for Taiwan a generation ago for use in AID's statistical tables, and who watched those inventions develop a life of their own, I would urge caution. Data on the correlation between population growth and GNP growth, for instance, may simply reflect some official's assumption at the time concerning what the relationship probably was. *Global 2000* has legitimately been faulted for taking questionable data too seriously; a good deal of caution is in order for all of us.

[35] "Globaloney 2000," p. 139.

[36] There is considerable danger that wishful thinking will color our perception. Kahn thinks that population growth is solving itself; there are "Jeremiads" who are trying to prove that present family planning efforts are solving it. Privately, they argue that, if they do not show some success, Congress will be loathe to continue supporting world family planning efforts, but one obviously does not see such an argument in print. Kahn may be unaware of the intense debate within the demographic community about whether and to what degree family planning efforts are bringing fertility rates down. Dr. Donald Bogue, whom he cites ("Globaloney 2000," p.137)—and whose findings are reported *in extenso* in *Global 2000*—bases his projections completely upon an unproven correlation between family planning efforts and fertility reductions. Bogue has long been known for his tendency to underestimate population growth. In 1966, his median projection for world population in 2000 was 4.527 billion—a figure the U.S. Bureau of the Census now believes was passed in 1981. Kahn incorrectly associates the UN with his guess as to when world population will stabilize, and he similarly associates the Bureau of the Census with his own figures on recent declines in world population growth rates. If he believes, as he says, that "most of the world's demographers" accept his and Bogue's assumptions, he should perhaps read Paul Demeny's "On the End of the Population Explosion," *Population and Development Review* (Population Council, March 1979).

[37] *The Global 2000 Report*, Vol. I, p. 3.

[38] *Global 2000*, Vol. III, pp. 65-66.

[39] *Ibid.*, Vol. II, p. 67.

[40] Simon does not address the argument advanced by Ulrich Peterson and R. Steven Maxwell ("Historical Mineral Production and Price Trends," *Mining Engineering*, 1979, 31(1): 25-34) that, in general, those commodity prices fell for two centuries until 1930 but have since been rising.

[41] "Globaloney 2000," p. 141.

[42] *The Next 200 Years*, p. 130.

[43] "Resources Unlimited", *Parade*, The Washington Post, Sept. 13, 1981.

[44] *The Ultimate Resource*, p. 41.

[45] *Ibid.*, Chapter 22, p. 9. His analogy of the population movement with the CIA and his use of epithets such as "racist" suggest, however, that his motives are more complex than he describes and that he is engaged in something of a vendetta against the population community.

[46] "Globaloney 2000," p. 132 and p. 146.